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ALLEGHENY FOREST EXPERIMENT STATION*

Occasional Paper No. 1
Forest Service

Philadelphia, Pa.
May 1, 1938.

RECOMMENDED TIMBER STAND IMPROVEMENT PRACTICES
IN NORTHERN HARDWOODS-HEMLOCK ON THE ALLEGHENY PLATEAU

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The beech-birch-maple-hemlock forest of the Allegheny Plateau differs from the northern hardwood-conifer type as a whole chiefly in its high proportion of black cherry, and the absence of spruce and balsam. The Allegheny Forest Experiment Station has since 1927 made this forest its chief subject for study. However, it still regards as tentative any recommendations it makes of silvicultural measures to be here applied.

Objects of stand improvement

The purposes of timber stand improvement are as follows: (1) To improve stand conditions within our forests for the growth of wood products, (2) To benefit wildlife and recreation, and, (3) To protect watershed and soil values.

Policy of ownership for public forests

Administration of publicly owned forest land, such as State and Federal Forests, involves the coordination of various uses of the forest for the benefit of the public. Measures for timber production must therefore take into account needs for wildlife, recreation, and watershed protection as well. The ultimate aim of timber management on public forests is to grow high quality long rotation crops of sawtimber and other products on a sustained yield basis. An important part of this task is putting our present day forest areas into shape by means of stand improvement measures.

Present forest conditions creating need for stand improvement measures

Past cutting by commercial owners, often followed by fire, has created large areas of culled old growth, and second or third-growth forest on the northern Allegheny Plateau. (1) of "References Cited", p. 12. These may be briefly described as follows:

- (1) Culled old growth mixed with second growth. Such stands resulted, in the absence of fire, from the logging of hemlock or white pine and leaving of a hardwood understory

* In cooperation with the University of Pennsylvania.

and scattered mature trees. Intolerant species seeded the openings made by logging and competed with advance seedlings of the understory to form new elements of the stand.

- (2) Second growth of even age which followed clear cutting of virgin stands for logs and chemical wood. In the absence of fire the usual stand is a mixed hardwood forest with a large percentage of black cherry beneath which persist sugar maple, beech, red maple, yellow and black birch and other species formerly present in the understory of advance growth in the virgin forest at the time of logging.
- (3) Third-growth stands which have resulted from the clear cutting of immature second growth for chemical wood. Because there was little or no advance growth of tolerant species beneath these young second-growth stands prior to logging, much of the new stand is made up of stump sprouts, particularly of black cherry and the maples, seedling pin (fire) cherry and black cherry. Pin cherry and most stump sprouts grow rapidly and may become formidable weed trees suppressing slower growing trees of better species and origin.
- (4) Stands of aspen and pin (fire) cherry which have resulted from repeated fires after logging. In such stands the stocking of desirable species is very poor, the natural return to better conditions is very slow and weedings are not practical.

Common stand conditions

In general within these four classes of forest resulting from past cutting or fire there are two common stand conditions affecting possible timber production:

- (1) A pronounced understocking of the entire stand, coupled with a lack of desirable tree species, origins, or tree form.
- (2) An over-crowding of natural stands of second growth and presence of defective trees and weed species which reduce both growth rate and quality.

Condition (1) is most frequently met with as the result of fire following heavy cutting or repeated clear cutting, while (2), over-crowding by both good and poor species, is usually found on the better sites in the absence of destructive agencies.

Corrective measures of general application

Fire protection is essential to prevent the addition of more depleted forest land to the forester's problem. Once a stand has been

depleted of good growing stock fire protection and natural restocking may result in satisfactory conditions of regrowth but all too often this is not true. Desirable future stands depend, not on fire protection alone, but also on the application of silvicultural measures to care for the developing new stand. These stand improvement measures are, (1) weeding in young growth, (2) thinning, liberation, improvement, sanitation and salvage cuttings in second growth, (3) improvement, liberation and final cuttings in old growth to insure adequate restocking of future stands.

Costs of stand improvement operations

Local data on the cost of various stand improvement treatments in northern hardwood stands are scanty and available figures vary widely with the kind of stand, intensity of treatment, skill of and wages paid to labor, supervision required and return from any marketable material cut. Since wage scales vary, figures of man hours per acre are of greater value in computing costs.

Weeding permanent sample plots on the Kane Experimental Forest in 13 to 18-year-old stands averaged 22 man hours per acre exclusive of the detailed marking necessary for study purposes.(2) The work was done by local experienced woodsmen using the ax and pulling all cut stems down close to the ground. No salable material resulted from this operation. The same crew weeded 21.5 acres of 13-year-old well-stocked sugar maple-black cherry-pin cherry stands at the rate of 29 man-hours per acre, inclusive of supervision by a foreman.

According to Cline (3) weeding of young mixed hardwoods on the Harvard Forest requires 8 or 10 man-hours per acre and best results are obtained by an initial treatment 4-6 years after logging followed by one or even two additional weedings three or four years apart. A stand developed to the small pole stage by two early weedings should be given an improvement cutting at 17 years of age followed by a first thinning at 25 years.(4) None of these early operations yield commercial products and labor will amount to about 28 man-hours per acre in stands approaching a second thinning. All subsequent thinnings should pay for themselves or show a profit through the sale of cordwood or small sawlog material where markets are available. The total direct outlay for early treatments will thus amount to about \$20.00 per acre for labor and \$10.00 per acre for supervision in an intensively managed forest.(4)

In thinning unmerchantable stands girdling of all trees 5" d.b.h. or over will be much cheaper and less damaging to the stand than cutting down these trees.(5)

Benefits of stand improvement

The possible benefits of stand improvement cannot be given in dollars and cents at the present time. Many are intangibles and may never be fully evaluated. A complete series of treatments applied to desirable reproduction will ultimately secure the following benefits:

- (1) Stands composed of the more valuable species at time of maturity.
- (2) More rapid growth in volume of these crop trees.
- (3) Crop trees of better form and quality which will bring a higher price per thousand board feet.
- (4) Less natural mortality and loss of volume due to disease and insect attack because of growing conditions favoring good vigor of crop trees.
- (5) Maintenance of soil or site quality, and watershed protection values.
- (6) Increasing food available to wildlife as a result of cuttings.
- (7) Improved aesthetic and recreational values.
- (8) Social benefits from continued production of forest crops, profitable employment, and stabilization of local communities dependent on the forest.

Kind of stand effectively treated and agency to do the work

In general all stand improvement operations will prove to be most effective when confined to the better stands and the better sites. The agency best fitted to do this work should be carefully considered for each stand or compartment treated. Where a commercial cut is obtainable, and can be readily marketed, contract sales of marked trees should be made. In other areas, local or CCC labor may be employed in stands too young to produce merchantable products, or too far from existing or possible future markets to be attractive to forest industries.

Priorities of CCC stand improvement work

First priority in CCC timber stand improvement work should be given the wooding of young growth stands between 5 and 15 years of age. Possibilities for betterment of stand conditions are greatest in such young well-stocked stands, and the danger of creating disease hazards is less than in older stands. Thinning of second growth is next in importance from the standpoint of benefit to the stand and much larger areas are available for this treatment than for any other. Liberation cuttings, especially those designed to release conifers beneath an inferior hardwood overstory, should be made in both second-growth and old-growth stands.

As a result of the glaze storm of March, 1936, covering 6,000,000 acres in Pennsylvania and New York, it will be necessary to make sanitation and salvage cuttings using CCC labor on unmarketable stands.

Stand improvement measures in young growth

Methods of weeding

Since it is impractical to treat all trees, or even all potential crop trees, on a given well-stocked area the accepted method of weeding is to select a certain number of crop trees and to remove only the trees which interfere with them. Choice of crop trees is usually considered necessary during the process of weeding. The attached list, (Appendix P. 1), classes all common tree species as (1) desirable, (2) less desirable and (3) least desirable. Choice of individual specimens depends on: tree species and origin, bole and crown form, defects, size, rate of growth, and spacing. (6), (7)

Treatment consists of removing only those trees overtopping the selected crop trees. Large sprouts between crop trees which threaten their future growth, though not at present overtopping, and badly-diseased or insect infested trees, should also be cut. Trees of crop tree quality between those selected at the regular spacing will be disregarded and no treatment for their benefit will be given. (6), (7)

The degree of release to be given should be based on the known habits of growth shown by seedlings and sprouts of various species. In general the tolerant sugar maple, hemlock and beech will require a greater amount of release (especially if previously subdominant due to competition) than will the already dominant and rapid growing intolerants such as black cherry, yellow poplar, cucumber magnolia and white ash. (6)

The most effective tool for use in very young (5-year-old) stands is the machete. (3) When the stems to be cut are larger than 2" a light ax is the best tool. Other tools which have been used are brush hooks, pruning shears, meat cleavers and heavy knives. (3), (9)

The number of crop trees selected per acre should always be greater than the number desired at stand maturity in order to insure against natural mortality and the failure of treatment in bringing all individuals through early competition. Figures obtained by the Station (6) indicate that in virgin hardwood stands 200 square feet is about the maximum basal area obtained. This would permit a stand of 143 trees of 16" d.b.h., 113 trees 18" d.b.h., or 92 trees of 20" d.b.h. per acre. At least double these figures should be used or 184 to 286 trees per acre in 10-15-year-old stands to allow for mortality and thinnings in subsequent years. A square spacing of 12-1/2 feet would give 279 trees per acre, and 15 feet about 200. Uniform spacing should be the ideal aimed at but must be sacrificed in order to select the trees best fitted to form the final crop. In selecting crop trees judgment as to the relative desirability of various trees on or near the properly spaced points must be exercised by each crew member. Deviation from proper spacing should be permitted but crop trees should not be spaced closer than 10 feet from an adjacent crop tree in 10-15-year-old stands.

Methods of removing weed trees will ordinarily be complete severance at any convenient stump height. When crop trees are small and there is danger of vigorous resprouting from adjacent large stump sprout clumps it will be advisable to make a partial severance of such weeds and bend down their crowns to discourage the formation of new sprouts. From the standpoint of decay hazard to crop trees it is very important to leave only a single stem (the crop tree) by basal severance of all other companion sprouts attached to the same root system. Even though certain valuable trainers are so sacrificed the danger of decay from future high unions, dead stubs, or future severances in thinning when the stems are larger and closer together will be avoided. Bending companion sprouts down and cutting with an ax is satisfactory, and, if the sprouts are under 1" or even 2" in diameter at the base there is little danger of decay. Avoid high stubs when subsequent growth will result in rubbing and injuring the bark of the favored sprout, and prevent damage to the crop tree stem.^{1/}

An efficient crew organization for the conduct of wooding work is made up of 4 to 8 axmen and an experienced foreman. Adequate instruction, examples of proper procedure and close initial supervision will be necessary until the men become thoroughly familiar with the work. This training should be given by a technically trained forester. Additional crews can be built up from this nucleus. Careful selection of crew members and a low rate of turnover will greatly reduce the wooding costs per acre. (8)

The area to be weeded can best be covered by the crew working abreast at stated intervals. Each man covers a strip 12 to 15 feet wide. The foreman should work back and forth behind the men inspecting the work and instructing and assisting members of the crew.

Foremen and subforemen will be in direct charge of the crew, and will be responsible for the kind of treatment given and the area covered. The technical forester or foreman should inspect the work frequently, check reports and maps, plan the areas and classes of treatment for all crews and make check tallies of sample plots with each foreman to determine the degree of compliance with instructions.

Pruning

In well-stocked stands of natural reproduction the artificial pruning of selected crop trees will seldom be necessary. Pruning of plantations made up of such conifers as white and red pine will, however, be justified in increasing the quality of the product. There is little known as to the cost, methods, or effects of pruning our native hardwood species.

Decay frequently enters the hardwoods through dead branch stubs, particularly when of large size. Since wounds created by pruning large live branches are also serious decay hazards it is necessary to confine such operations to the small branches of young crop trees. It is gener-

^{1/} From memoranda in files and note in Forest Research Monthly Report, U. S. Forest Service, of December 1937, p. 26, by Dr. W. A. Campbell.

ally agreed that branches larger than 1 inch or at most 1-1/2 inches in diameter should not be pruned.(10) Pruning may also check the growth of a tree when too drastic a reduction of the length of live crown is made.(11)

In understocked, limby, hardwood young growth, weeding in the sense of releasing crop trees may not be required, but removal of companion sprouts at the base of all prospective crop trees and pruning to keep down limb size are both measures which will reduce future decay and should markedly increase the chances of producing material of greater value than fuelwood.

Mowing advance growth

It has been commonly observed that sapling and smaller advance understory sugar maples are frequently of poor form and are damaged by Noctria cankers. It is known also that the seedling-sprouts resulting from cutting back such advance growth are superior in form, health and growth rate to the original seedlings.(12) Weak sprouting species such as beech and the birches will of course be discouraged. This operation had best be done during the late winter or early spring before rapid growth begins and not during the height of the growing season. If done as a separate CCC operation it should ordinarily follow immediately after a winter logging job is completed. A brush scythe or brush hook will prove to be the best tools to use in this work. All conifers should be preserved from mowing and this work had best be confined to areas supporting a dense understory of saplings or small whips made up chiefly of suppressed sugar maple. When the bulk of the understory stand is made up of the weakly sprouting species, such as beech and the birches, mowing should not be done.

Treatment of stumps to eliminate or reduce sprouting

One of the chief reasons for weeding young growth stands is to remove aggressive wood-tree elements which have dominated desirable crop trees. These wood trees are frequently the vigorous wide-spreading stump sprouts of such species as red maple and black cherry as well as trees of the least desirable species. It is possible as an aid in subsequent weeding to prevent the sprouting of stumps or at least reduce the vigor of such sprouts. This form of stand improvement is applicable to areas from which immature second growth has been clear cut and may be used where the land is more valuable for future sawtimber production than for cordwood.

Methods being tested by the Station following a glaze sanitation and salvage cutting in 40-year-old second growth include girdling of stumps, peeling bark to ground line and knocking off the sprouts during mid-summer.(13) Other possible methods include the application of Diesel oil or sodium arsenite. Evidence at hand indicates that cutting or breaking off the first or second seasons' sprouts in mid-summer will prevent resprouting in about 60 percent of all black cherry stumps treated.(13) Since black cherry stump sprouts are the worst wood-tree offenders and the rot hazard is high in sprouts of this species their early elimination is recommended in stands dedicated to sawtimber production.

Inter- and underplanting

In many cases the only possible means of improving the stocking and species composition of open-grown stands would seem to be through the interplanting of conifers. Red pine is known to be the most successful species to use on the well-drained sites when stand density of native hardwoods is not too great. Irregular spacing to avoid clumps or dense patches of established growth may be used.

Underplanting of the better stands of the beech-birch-maple-hemlock forest region is not a practical method of improving the young growth due to high initial cost of establishment, slow growth of the understory and difficulty of bringing it through the severe competition offered by native hardwood reproduction after the release cutting is made. In fire-degenerated stands of aspen-pin cherry, underplanting with spruce offers a means of improving the composition.⁽¹⁴⁾ Since competition by the better hardwood species is not serious there is a good chance of the spruce coming through successfully after the aspen and pin cherry are cut.

Stand improvement measures in second growth

Thinnings and improvement cuttings

When an initial improvement cutting has been delayed until the stand has reached an age of 40 or more years it is usually impossible greatly to change the species composition or the form, health, spacing, and quality of the dominant stand. It is evident that improvement cuttings or thinnings should be preceded by woodings and cannot alone produce a high quality stand. Where markets for cordwood exist it will be best to thin as soon as sufficient material to pay for the operation is available, or about 25 to 30 years of age, and continue to make light thinnings at about 10 year intervals until the time of final cutting.

Second-growth stands in northwestern Pennsylvania, of sufficient age to be profitably thinned, are frequently dominated by black cherry or holdover beech of cordwood form. The improvement cutting practice recommended in such cases depends largely on the availability of desirable species of potential crop-tree calibre associated with these cordwood elements. Plot studies by the Allegheny Station indicate that cutting of the most defective trees in 40-year-old stands (or about 10 cords per acre) seriously breaks the crown canopy and thus increases the hazards of sun scald, windthrow and windbreakage, and glaze damage to the reserved trees. The birches and to a lesser extent beech, will not survive a heavy opening of the stand and cannot be depended on to form a reserve growing stock. Sapling and small pole-sized sugar maple of single stemmed clear-barked character form the ideal crop trees and respond well to a release cutting from above. Stands made up chiefly of black cherry and sugar maple may thus be given the necessary thinning from above, to remove dominants of cordwood form with a reasonable hope of leaving a successful reserve stand of desirable species, good form and origin, proper spacing and low mortality.⁽¹⁵⁾ On the other hand stands in which yellow and black birch

are dominant, or form the chief understory, are practically impossible to improve by cuttings made in older stands of second growth. Hindsight indicates that early weedings or even some change in the cutting method used on the original stand would have bettered the composition of such stands. The practical answer to the question of what may be done at the present time in such stands is not known. Until studies give this information it is recommended, (1) that stand improvement cuttings or thinnings in stands with high percentages of the birches be given a low priority unless glaze damage or dying of birch is serious, and (2) that any cutting be made as light as possible and as frequently as possible with the idea of gradually replacing the undesirable elements without excessive exposure of the site as contrasted with heavy infrequent cuttings.

Studies by the Bureau of Plant Industry indicate that severance of companion sprouts in stands over 20 years of age is dangerous from a decay hazard standpoint. In stands which were not wooded when young it is best to either cut all members of a sprout clump or leave them entire to lessen decay entrance from cut stubs. (16)

Sanitation and salvage cuttings

Where existing road systems and markets permit, commercial sales of severely damaged stands should be made in glaze susceptible areas. The treatment to be given each stand will vary with the degree of glaze injury sustained and the character of the original stand. In lightly damaged stands of desirable second growth, partial cutting to remove only severely damaged trees should be used. Clear cutting may be the only solution in badly damaged stands. In either case the effort should be made to preserve any undamaged pole sized understory of desirable species such as sugar maple, hemlock, etc., as the nucleus of the future stand and to follow out the technique recommended for stand improvement cuttings wherever possible.

Definite plans for early stump treatment, mowing and wooding of this third growth should be made, especially in the case of areas from which immature stands of second growth have been clear cut. The policy should be to encourage the growth of any native conifers on the exposed ridges or north slopes likely to be glaze damaged in the future, since it has been found they resist this form of injury much better than any of the hardwoods. (17)

Sanitation cuttings for the reduction of Noctria cankered or other diseased trees should be based on principles outlined for glaze damaged stands. Grant (18) suggests the possibility of converting severely cankered hardwood stands, which are potentially valuable for softwood sawtimber production, by the spot planting of conifers (spruce, fir, and pine), together with release of any natural softwood reproduction, as a slow but rather inexpensive way of getting such marginal stands into permanent production of valuable disease free species.

Liberation cuttings

A fairly common stand condition noted in the beech-birch-maple-hemlock forest region is the suppression of an understory of hemlock by an inferior overstory of hardwood such as decadent beech, less desirable red maple, or birches subject to the bronze birch borer. Such stands will be improved by a liberation cutting to release the hemlock. Examples of very rapid growth of hemlock after full release by past cuttings, or after windthrow of the overwood in virgin stands, give assurance of the ability of suppressed trees to respond. Either girdling or cutting down the hardwood overstory may be used. Girdling will prove cheapest in labor used, will probably damage the hemlock less and is justified where there is no market for the hardwood to be removed. A complete treatment removing all the overstory at one time is the practical method to employ and should result in little damage to the understory hemlock because of exposure. If the understory hemlock is also suffering severe competition with hardwood reproduction the treatment should also include a weeding to remove stems of the hardwood species either by complete or partial severance or by girdling larger individuals.

Similar liberation and weeding treatments could be used in the case of white pine reproduction found beneath poor quality second or third growth hardwood stands, providing weevil and white pine blister rust control funds are available. Except for the removal of occasional wolf trees hampering reproduction on clear cut areas, it will usually be unnecessary to make special efforts to release hardwood advance growth of the desirable tolerant species prior to final cuttings. This is particularly true of fully stocked second-growth stands beneath which desirable tolerant advance growth seedlings are usually small, and not to be depended on to dominate the new stand in competition with the intolerant wood elements.

Stand improvement measures in old growth

The final harvesting of old growth or mature second-growth stands and their replacement by desirable young growth is not usually thought of as a stand improvement operation. Actually the method of final cutting used is one of the most important factors in either building up or in deteriorating the forest growing stock.

It is generally accepted that certain partial cutting systems of harvesting mature timber are to be preferred to clear cutting in the beech-birch-maple-hemlock forest region particularly where a well formed understory is lacking. This is based on the fact that partial cutting by either a tree selection or shelterwood system, using a sawtimber rotation, maintains stand conditions favoring the bulk of the desirable species, while clear cutting, especially on a short rotation, favors the intolerant wood species and trees of sprout origin.(19) The selection system should be used where stands are accessible and a continuous yearly supply of quality products is desired, providing the given stand has a structure, i.e. representatives in all diameter classes, adaptable to this method. Where such conditions do not exist, a shelterwood method of cutting should be applied, while in very

defective old growth with an abundant understory of desirable species clear cutting may be the only solution possible.

Stands of virgin timber in public ownership, which are being held for timber management purposes, are rare but there are many areas of culled old growth mixed with second growth which are now merchantable. Treatments designed to improve these latter stands should be confined to those in which the overstory is very defective and where an understory of reproduction of desirable species is very sparse. In order to encourage the development of the necessary advance growth to form the basis of a new stand it will be necessary to girdle or cut some of the dominant trees to make openings in the canopy. The trees selected for removal should be widespreading individuals of defective bole form or health and of least commercial value especially if girdling is the method used. In both the selection and shelterwood system it is advisable not to leave beech and the birches in an exposed position because of the danger of mortality. Following the establishment of this understory, final cutting may, if necessary be delayed for a number of years without killing out the very tolerant seedlings of sugar maple, beech and hemlock. Such a method of stand improvement is in effect a shelterwood cutting and the final cutting should completely remove the overwood.

Following a final cutting by the shelterwood, or the clear cutting system, it is essential to provide for weeding of the new growth as previously outlined, in order to discourage weed tree dominance of the advance growth. Less of this kind of work will be required in stands handled on a tree selection basis because the weed species are usually intolerants.

Use of commercial timber sales should be made wherever possible as a tool in stand improvement. In all final cuttings careful consideration of the silvicultural system to be used and marking of the individual trees on the ground is essential. Since cutting on a short rotation will not yield high quality products and will result in deterioration of the new stand, final cuttings should be made only in old growth or mature (80-120-year-old) second growth.

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Appendix

FACTORS TO BE CONSIDERED IN THE CHOICE OF INDIVIDUAL CROP TREES IN WEEDING, THINNING, AND STAND IMPROVEMENT PRACTICES IN THE BEECH-BIRCH-MAPLE-HEMLOCK FOREST REGION

I Species:

Relative desirability of common species for sawtimber production.*

<u>Desirable</u>	<u>Less desirable</u>	<u>Least desirable</u>
Sugar maple	Yellow birch	Pin cherry
White ash	Sweet birch	Aspen
Black cherry	Basswood	Striped maple
Eastern hemlock	Red maple	Mountain maple
Yellow poplar	Elm	Serviceberry
Cucumber magnolia	Paper birch	Blue beech
Beech	Gray birch	Hop-hornbeam
Red oak	White pine	Hawthorn
		Mountain ash
		Boxelder

II Origin

Well developed seedlings, or sprouts arising from small stumps 2 inches or less in diameter (commonly called seedling sprouts) are to be preferred as crop trees. When trees of such origin are not available sprouts of sugar maple from stumps 3-10 inches in diameter may be treated to produce a single crop tree stem by severance of all companion sprouts on the same stool. Decay hazard is light provided this work is done in stands 5-15 years of age. Sprouts originating at 2 inches above ground or less and from small stumps (3-6 inches in diameter) are to be preferred. Sprouts of black cherry and red maple from stumps 3-10 inches in diameter are very aggressive and are less desirable as crop trees even when of root collar origin.

Root suckers of beech and sugar maple may be used as crop trees providing they meet other requirements.

Sprouts from the sides or top of large stumps are undesirable in the case of all species and decay hazards are high, especially when they

* Based on the technical properties of the wood, and such factors as vigor and growth rate, ability to endure competition, mature size, form, reproductive ability, and freedom from disease, insect and animal damage. Present market value and value for wildlife food, or erosion control, considered as secondary factors.

originate at points above the root collar.

III Bole and crown form

Crop trees should be the straightest individuals possible to select with the main stem continuing up through the crown. Crooked or forked trees will be discriminated against especially if the fork is at a point below 16 feet or one log length. Limby widespreading trees should ordinarily not be selected because of the low grade of lumber produced and their tendency to "wolf" growing space. Trainers to discourage the formation of persistent low side branches should be left, particularly around rapid growing intolerants such as black cherry, white ash, basswood and yellow poplar. Trees which have had their crowns badly damaged by glaze should be discriminated against in stand improvement operations.

IV Defects

Injuries due to disease, mechanical wounding, rodent damage, insects, climatic injuries and other causes influence the health of trees. In picking crop trees a careful examination and evaluation of the seriousness of any visible defects must be made.

A common disease in northern hardwood species is cankering caused by *Nectria* sp. Red maple is most susceptible to this disease and cankered stems should not be chosen as crop trees. Sugar maple is also subject to this disease but vigorous young crop trees will probably outgrow small cankers if released by weeding. Open wounds caused by fire, logging, wind or glaze breakage, porcupine gnawing, drought or sunscald, are serious defects in any tree considered as a crop tree specimen and become entrance points for fungi and insects. In general the larger the size or greater the number of such wounds the less the value of the tree. Wounds with fungus fruiting bodies show definitely that the tree should not be favored. Poor risk trees expected to die before the next cutting operation should be salvaged in any stand improvement operation.

Of common insect enemies the bronze birch borer, *Agrilus anxius* Gory. causes serious losses in yellow and black birch. Because of this the birches should never be exposed by heavy cutting or on a south-facing forest edge and should be favored as crop trees only on north-facing slopes and stream bottom sites. The sugar maple borer is also a serious pest as are the living beech and the hemlock borers.

V Size and rate of growth

The mature size of all the desirable and most of the less desirable species listed is satisfactory for sawtimber production. The most rapid growing desirable species are black cherry, yellow poplar, cucumber magnolia and white ash when represented by dominant trees on good sites. The other desirable species are tolerant and capable of very slow growth when suppressed, but respond to release and make very satisfactory growth when

uncrowded. In weeding practice it is a general rule to select crop trees of average or slightly above average height. Trees too far above the average tend to develop into wolf trees while those beneath the general crown canopy have under-developed roots and crowns and may not respond satisfactorily to treatment. The extremely rapid initial growth rate of black cherry sprouts and their tendency to spread and fork is another factor making them undesirable as crop trees in stands to be managed for sawtimber of high quality. In thinnings or improvement cuttings careful judgment is necessary in order to select trees which will respond to treatment by increasing their growth rate and to concentrate this growth on high quality trees. The use of an increment borer in determining the past rate of growth in trees of various species and crown classes is recommended as a check on general observation.

VI Crop tree spacing, either in the initial weeding of a stand containing 2000 to 5000 or more trees per acre, or in the thinning of an older stand, cannot be made mechanically perfect. Lack of exact uniformity in spacing of crop trees is less of a fault than failure to select the best individual trees occupying the given area. Approximately 280-300 crop trees per acre should be selected in stands 10-15 years of age and a square spacing of 12-1/2 feet should be used as a guide. In crew work each man must judge the relative desirability of various trees on or near the properly spaced points and if none are suitable must proceed along this line noting all trees on either side to a distance of about 6 feet until a desirable tree is found. No crop tree should be closer than 8-10 feet from an adjacent crop tree in 10-15-year-old stands.

